SOLUTIONS TO HIPPO VALLEY EVAPORATOR PROBLEMS

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Abstract

Hippo Valley (HV) sugar factory is located in the south-east area of Zimbabwe. For many years, HV has experienced problems with low Brix syrup and high undetermined loss. Over a period of four years, a number of corrections and changes were made to the evaporator station to improve syrup Brix and Vapour 1 pressure. Rearrangement of the evaporator condensate flash pipe layout eliminated uncontrolled condensate flashing. The pressure and temperature differences across the evaporators increased. Incondensable gas removal systems were changed to eliminate preferential removal of light incondensable gas from the Roberts evaporators and provide separate light and heavy gas removal. The combined result of the flash and incondensable gas changes was an improvement in syrup Brix from well below 60\% on average to 63\% after the changes. Elimination of excessive entrainment from the Kestner separator and the two last effect evaporator vessels contributed to a reduction in undetermined loss (UDL) from 6-7\% down to about 1\%. Planned changes are in place to further reduce undetermined loss and improve evaporator operating efficiency. This paper covers the details of the changes that were implemented.

Keywords: entrainment, juice flash, feed rings, entrainment separator, entrainment return, partial feed flash

Background

Hippo Valley (HV) has two identical quad evaporator lines. In each evaporator line the first effect consists of two long tube Kestners in parallel, followed by single 2nd, 3rd and 4th effect Roberts vessels. Both evaporator lines are designed to cater for a total crush rate of 440 tons cane per hour (TCH).

From 1995, HV began to experience a few problems in the factory and these problems continued to grow over time. Historic performance data highlighted problems with low syrup Brix, high undetermined loss, low imbibition rate, low Vapour 1 (V1) pressure, high sucrose contamination of V1 condensate, and a number of other factory parameters. Many of these problems continued to escalate until the end of the 2006 season.

During the 2006/2007 offcrop, Tongaat Hulett Sugar Technology and Engineering Group (TEG) worked in liaison with HV staff to increase syrup Brix from average levels of well below 60\% to >63\%, as well as to reduce the erratic high undetermined loss from values of >6-7\% down to acceptable values of <2\%. This was the start of a process that has continued up to the time of writing this paper.
Evaporator problems and solutions

Syrup Brix

Evaporator condensate and flash arrangement

In 1996, HV started operating a new evaporator station consisting of rising film plate evaporators. As a consequence of inadequate heating surface area and excessive fouling, the performance of the station was very poor. At the end of 1999, the original evaporator configuration was reinstated and the plate units were decommissioned. However, the performance of the evaporators remained sub-standard up until the end of 2006.

During the period 2000 to 2006 the average annual syrup Brix varied from as low as 40.4% to a maximum of 57.5%. Imbibition % fibre dropped to <300 on average for this period. Clearly some change had been made to the original evaporator station that was adversely affecting performance. The layout of the current evaporator station was compared with the layout that was in place when the average annual syrup Brix was >60%.

The arrangements of the condensate and flash systems before and after 2007 are illustrated in Figures 1 and 2, respectively. Anomalies found in the condensate and flash configuration before 2007 explained the poor performance of the evaporators.

As a general rule, where condensate from any effect flashes to the following effect, a steam trap is required on the condensate stream to ensure that the steam or vapour from that vessel does not follow the path of the flash to the next effect. If no steam trap is present, then the pressure difference between the calandria and the flash line will result in steam or vapour moving from the calandria to the flash area without restriction. In theory, the end result is that calandria pressure and flash pressure can equalise if the open pipe areas are large enough. When this happens boiling will stop in the vessel where the flash is directed.

The configuration of the evaporators from 2000 to 2006 was designed to capitalise on feed forward flash to the following effect. The Gestra steam trap in the condensate line from the Kestner ensures that condensate alone will travel down this line to the exhaust condensate tank. The absence of steam traps in the condensate lines from the 2nd, 3rd and 4th effects provides no protection from continuous movement of exhaust flash all the way down to the 4th effect calandria. Since the flash lines are large 300 mm pipes, substantial flash can take place from each of the condensate tanks. The end result is a reduced pressure and temperature difference between the exhaust steam and the Vapour 3 (V3). The driving force for evaporation was diminished and HV struggled to achieve reasonable syrup Brix.

Solution to low Brix syrup

Steam traps were required on the V1-V3 condensate outlets from the 2nd, 3rd and 4th effects. Mechanical steam traps can be used, but these are expensive and are maintenance intensive. An alternate steam trap can be created by converting the flash line to a balance line on each of the V1, V2 and V3 condensate tanks. This allows condensate to leave each vessel and accumulate in the relevant condensate tank.

If the level in the condensate tank is controlled, then no flash will take place because there is no pressure differential between the tank and the calandria. However, if the condensate flow from the V1 condensate tank to the V2 condensate tank is controlled and the V1 tank level stays constant, then the V1 condensate that flows to the V2 tank will flash to V2 via the balance pipe. Similarly, the control of level and flow of condensate from the V2 tank to the V3 tank will result in controlled flash.
Figure 1. Flash and balance lines (2000-2006) prior to the changes made.

Figure 2. Flash and balance lines (2007-present) after the modifications.
**Evaporator incondensable gas extraction systems**

Anomalies existed in the incondensable gas extraction systems in all 2nd, 3rd and 4th effect Roberts vessels. The most common arrangement in these vessels consisted of a vertical triangular closed channel located opposite the vapour inlet. Each triangular channel had 8 x 50 mm diameter incondensable gas vents located along its vertical length. The triangular channel vented from the inside of the calandria via 3 x 50 mm pipes that connected into a single external 50 mm vent pipe with an isolating valve (Figure 3).

The problem with this system was that the light incondensable gases vented preferentially, leaving the heavy incondensable gases in the calandria. Non-venting of the heavy incondensable gases reduced heat transfer in the lower section of the calandria and this anomaly contributed to low syrup Brix.

An expedient change was made to the incondensable gas venting system after the start of the 2007 season. Both the lower 50 mm pipes from the calandria were blanked and the top 50 mm vent was left open. Light incondensable gases vented through this modified system.

A 50 mm pipe was attached to the top of the condensate outlet box to allow for venting of heavy incondensable gases. This pipe had a manual valve to regulate the flow of heavy gases to the body of the 4th effect vessels. The original and modified arrangements are shown in Figure 3.

![Figure 3. Original and modified incondensable gas venting.](image-url)
Result
The changes to the flash system were implemented during the 2006/2007 offcrop in readiness for the 2007 season. The change to the incondensable gas system was made in June 2007. The weekly syrup Brix trends for 2005, 2006 and 2007 are illustrated in Figure 4, which clearly shows the syrup Brix improvement in 2007. HV managed to achieve syrup Brix of 63% at an average imbibition % fibre of 340. The average crush rate was 325 TCH. Progress had been made and the evaporators were no longer a massive restriction to throughput.

![Weekly syrup Brix trends for 2005-2007](image)

**Figure 4. Weekly syrup Brix trends for 2005-2007, showing improvements after changes to the flash system in 2006 and incondensable gas system in 2007.**

2007-2010 and the refurbishment programme

Zimbabwe suffered severe economic problems from 2007 to 2010, and HV experienced many problems during this period. The state of the plant deteriorated considerably and the standard of performance had dropped to an abysmal low by the end of the 2009 season. A plant refurbishment programme was initiated during the 2010/2011 offcrop, and continued into the 2011/2012 offcrop. Some of the key issues that were addressed in the refurbishment included:

- Leaking and damaged cooling pond piping was replaced with 3CR12 piping. The improvement in water cooling helped to improve vacuum by 2-3 kPa in both the pans and the evaporators.
- High pressure water cleaning and partial replacement of Kestner tubes produced a small improvement in evaporator vacuum and syrup Brix. A decision was made to replace the tube plates and tubes in both the A and B-line Kestners. At the same time separate light
and heavy incondensable gas extraction systems replaced the single gas extraction system that gave preference to light incondensable gas removal. The Gestra steam traps were refurbished and an improved feed system was installed. The A-line was completed in the 2011/2012 offcrop. The B-line will be completed in the 2012/2013 offcrop.

- Replacement and refurbishment of pumps, instrumentation, piping and vessels continued throughout the two offcrops.
- Changes were made to the Kestner separator feed. Details of this are contained in the next section of this paper.

**Low V1 pressure and sucrose contamination in V1 condensate**

Low V1 pressure (10-20 kPa(g)) and a high level of sucrose contamination in V1 condensate (>50 ppm) were experienced. The original two tray design inside the Kestner separator was replaced with a single pipe feed and splash tray a few years prior to 2006. The design of the Kestner separator was checked, but no obvious problems were detected.

At the beginning of the 2009 season some serious fouling of the Kestner tubes took place on the A-line evaporators. This prompted a careful examination of the Kestner and associated equipment throughout the season. At the end of the season the entrainment separator systems in the Kestner separators on both the A and B-line evaporators were examined. A heavy build-up of carbon in the entrainment separators activated alarm bells. The carbon build-up was substantial and had blocked off more than 50% of the open area in the entrainment separators. This was obviously the cause of the high sucrose contamination in V1 condensate. The question was how the contamination was taking place.

A thorough examination of the Kestner separator design coupled with the 2nd effect height and tube configuration, gave rise to some ideas. The following hypothesis was considered a possibility:

*The two Kestners in each evaporator line are connected separately to the single Kestner separator by large juice delivery pipes. The single delivery pipes from the two Kestners feed into opposite sides of a single feed pipe that traverses the lower section of the Kestner separator (Figure 5). The Kestner separator feed pipe is too low and is periodically submerged below the normal juice level in the separator. Vapour flash from the feed pipe below the juice level will cause violent eruptions of juice and result in high entrained juice loads on the entrainment separator. The end result will be carbon formation in the entrainment separator, sucrose contamination of the V1 and a reduction in V1 pressure due to a large pressure drop across the entrainment separator. The same situation will apply to both the A and B-evaporator lines.*

Since the factory had stopped for offcrop maintenance, there were a few challenges that were faced to establish whether the consideration was true. An investigation to uncover facts associated with the hypothesis was undertaken. The following facts were noted:

1. Observations inside the Kestner separators clearly showed a band around the separator that marked what appeared to be the periodic high level that the juice reached in the Kestner separators. The juice level was almost level with the top of the inlet pipe into the separators (Figure 6).
Figure 5. Double juice feed into Kestner separator on each evaporator line.

Figure 6. Juice level in Kestner separator above the juice inlet pipe.
2. The openings at the bottom of the inlet pipes into the Kestner separators are about level with the operating floor level. The sight glasses on the Kestner separators were not in good condition and it was not possible to see what was taking place in the separator under normal operating conditions.

3. The top of the tube plates in the 2nd effect vessels are about 3 m above the operating floor level.

4. Since the sight glasses of the 2nd effects are very high and relatively inaccessible, the operators tended to operate with juice clearly visible in the second sight glass above the calandria. The juice in the sight glass can be seen by the operator from the floor level without having to climb up scaffolding to look into the vessel.

5. The V1 pressure was lower than normal due to complete blockage of many Kestner tubes.

6. The Kestner entrainment separators were blocked with carbonised sugar material (Figure 7.)

The listed facts indicated that the juice level in the 2nd effects was frequently very high when juice was observed in the second sight glass above the calandria. To maintain the high level in the long-tubed 2nd effect, the V1 pressure in the Kestner separator had to be high and/or the level in the Kestner separator had to increase. The V1 pressure was in fact low due to blocked Kestner tubes; therefore the juice level in the Kestner separator had to increase. When the juice level in the Kestner separator increased, the feed pipe in the Kestner separator became submerged in juice. Flash from the feed into the Kestner separator resulted in massive eruptions of juice, sucrose entrainment and eventual blockage of the entrainment separators.

Figure 7. Carbonised scale removed from entrainment separator.
The solution

The solution to the problem was to raise the feed pipe above the high juice level mark in the Kestner separator.

Raising the pipe would reduce the disengagement height between the feed pipe and the entrainment separators located above it. It was agreed to raise the feed pipe to easily clear the normal high juice level in the Kestner separator. Although the disengagement height above the feed pipe was reduced to 1.8 m, it was felt that this would be adequate given the downward trajectory of the juice from the feed pipe onto the splash plate in the Kestner separator. The new position of the modified feed from one of the Kestners is shown in Figure 8.

The entrainment separators were cleaned and the mechanical changes to the feed pipe height were engineered and completed during the offcrop.

![Figure 8. Modified feed from one Kestner into the Kestner separator to reduce entrainment.](image)

The result

At the start of the 2010 season, the sucrose contamination in the V1 condensate dropped from about 50 ppm to about 5 ppm. The V1 pressure increased substantially from 10-20 kPa(g) to levels of 50-60 kPa(g) on the pan floor. Instead of pan boilers trying to reduce syrup flow to the pan floor, there was now a persistent request for the front end to speed up to provide more syrup for the pan floor.
Although the situation improved substantially, there was still a small build-up of carbon on the entrainment separators over the next two seasons spanning 2011 and 2012. This highlights the need to clean the louvre type entrainment separators every year, and to continuously check that the Kestner separator feed pipe is not submerged in juice.

**Undetermined loss**

*Background*

From 1995 the undetermined loss (UDL) at HV increased to 3% or more. There were occasions when values of >10% were experienced in 2008 and 2009, due mainly to failure of fatigued plant and minimal maintenance driven by shortage of money. On completion of the 2009 season, money was invested in plant maintenance over a period of two offcrops, and the situation reverted back to undetermined losses of about 3-4%.

After the plant had been repaired and/or replaced and was operating normally, there was still considerable sucrose entrainment into the factory cooling water system during the 2011 season. The evidence was visually overwhelming in the form of thick, cream-coloured froth that stood up to 2 m high above the hot water seal well. Figure 9 shows the froth flowing over the ground floor area of the factory.

Since this froth was observed predominantly at the tailpipes of the A-batch pans, checks were done on the pan entrainment separation systems. The designs of conventional top hats were fine; however, three A-pans had small snail separators with unacceptably high vapour velocities. A slightly modified top hat with the entrainment return located below the vapour outlet pipe was designed for these three A-batch pans. The pans were modified during the 2011/2012 offcrop.

At the start of the 2012 season, sucrose entrainment into the cooling system did not abate. The first thought was that the three A-pans which had been modified with new top hats were to blame. Time was spent investigating this possibility. A splash plate was installed below the entrance to each of the top hats as an added precaution against entrainment. Continuous visual monitoring of the pan entrainment return sight glasses for a number of complete pan cycles showed that minimal entrained material was present in the top hat. It was eventually concluded that the pans were not the main cause of the high sucrose entrainment, and that the source of the entrainment had yet to be identified.

![Figure 9. Sugar entrainment froth flowing on factory floor.](image)
Observation of entrainment

Since the pans had been ruled out as major contributors to sucrose entrainment, all attention turned to the evaporator station. On the surface, there were no obvious signs of heavy entrainment from the last effects on both the A and B-lines. The operating conditions appeared to be normal.

It was decided to take a more critical look at the evaporators. A number of checks were carried out and the following changes and findings were made:

- There was inadequate lighting on the sight glasses on the A and B-line 4th effects.
- The lighting sight glasses were scaled up and allowed limited light into the 4th effect vessels on both A and B-lines.
- The sight glasses on the working face of the last effects were either badly scratched from cleaning or were scaled up, so no depth of vision was available in the vessel.
- No entrainment return from the top hat entrainment separators flowed back through the sight glass on the B-line and only a small volume flowed back on the A-line. However, it was difficult to clearly see as the sight glasses were very small and were stained. At that stage it was concluded that little if any syrup had reached the top of the vessel and entered the top hat.
- When the manhole on the top of the A-line was opened there were signs of syrup present in the top hat, showing that syrup was indeed getting into the top hat in the last effect.
- The entrainment return line from the top hat of the A-line was opened and a large amount of rounded scale/carbon objects were removed from the pipe. These objects were sufficiently large to markedly restrict the flow of entrained syrup from the top hat back into the vessel, hence the small flow that was observed in the entrainment return line.
- The 4th effect on the B-line had no manhole to access the top hat area of the vessel for inspection purposes. It was decided to install one on a maintenance stop day. When a cut was made into the wall of the vessel in the top hat area, syrup flowed freely from the cut for an extended period (Figure 10). The volume of the flow suggested that the entire top hat was full of syrup.

![Syrup]

Figure 10. Syrup flowing out of the cut in the top hat.
• When the syrup had drained, a hole was cut for the manhole installation. On entering the top hat area, a strip of 10 mm thick metal was found covering the outlet to the entrainment return pipe. The metal strip had the same radius as the vessel wall and was about 120 mm wide x 700 mm long (Figure 11). It was a snug fit and ensured that the exit from the top hat to the entrainment return system was completely blocked. It was later established that this piece of metal had fallen into the top hat during alterations and maintenance of the vapour piping. The space at that time was not large enough for a man to enter the top hat and remove the metal strip.

![Figure 11. Curved metal strip that restricted entrainment returns from the top hat.](image)

• It was decided to replace the entrainment return sight glasses with new large diameter glasses. The end of the return pipe was redirected from the saucer to a position above the calandria. A light was installed behind each sight glass.

• Calculations were carried out to determine vapour velocities at various points in the top hat. It was established that a part of the skirt on the opposite side to the vapour outlet from the top hat had to be cut off to reduce vapour velocity to <40 m/s. Space was limited so only part of the cut could be made. The rest would have to be completed in the offcrop.

• At this stage it was concluded that spouting of syrup must have taken place for syrup to end up in the top hats of both 4th effect vessels. Spouting in the last effect can be due to one or more of the following:
  - Air leaks in the saucer below the calandria.
  - Vapour ingress into the vessel through tube leaks.
  - Damaged or incorrectly designed feed rings.
  - Flashing of condensate leaks into the vessel.

• Vacuum was raised in the 4th effect vessels to check for leaks. The calandria was pressure tested and no leaks were found.

• When the manhole at the bottom of the A-line 4th effect was opened, it was noted that the individual feed system pipes had partially or completely separated. Evidence of severe spouting was observed where the syrup fountain had de-scaled and formed a small shiny area on the bottom tube plate of the calandria. Where the sections of the feed pipe had completely separated, the shiny area was much larger (Figures 12 and 13). The massive
forces associated with the excessive flashing and vapour production had physically sheared the bolts that held the feed ring together.

- When the B-line was opened, a similar situation was observed.

Figure 12. Partially separated feed ring that resulted in spouting of syrup and subsequent entrainment.

Figure 13. Total separation of feed system pipe sections that resulted in syrup spouting and entrainment.

At this stage it was concluded that the answer to the spouting in both the A and B-line evaporators had been uncovered, namely damaged feed rings in the last effects. The solution was to reassemble the feed rings and continue with operations. As a precaution against the large forces in play, the feed ring nuts were welded to the bolts.
The feed rings were re-assembled and after the start up, large volumes of syrup return were seen in both the new A and B-line entrainment return sight glasses. HV was under pressure to crush cane, so operations continued. The sucrose levels in the cooling water remained very high at >4500 ppm and the undetermined loss for the next few weeks remained very high.

HV continued to work on improving observations into the vessels through the sight glasses. Sight glasses were cleaned or replaced and new key sight glass locations were identified and sight glasses installed. The changes improved visual observations in the vessels, particularly in the A and B-line last effect vessels.

The entrainment return flows from the top hats in both the A and B-lines remained abnormally high. Severe spouting of syrup could be clearly seen. Observations through the top sight glass located on the conical section on the top of the 4th effect, showed a number of syrup fountains spraying intermittently to a height of about 4-5 m. The individual fountains were situated above the individual holes in the feed ring. The feed ring design had been checked and it was correct. Entrainment return sight glasses were also intermittently running full of syrup.

Observations of very high pressure differences of >50 kPa(g) between the 3rd and 4th or last effect vessels on both the A and B-line raised some questions. A test was done to observe the spouting when feeding from the 3rd to 4th effect and then stopping the feed. Visual observations in the vessels showed a cessation of spouting when the feed was stopped (Figure 14). At the same time the entrainment return stopped flowing when the feed was stopped. The spouting started again when the feed started and the entrainment return flow also started.

![Figure 14. Entrainment return with (left) and without (right) feed to 4th effect.](image)

A very large pressure drop between the 3rd and 4th effects will contribute to excessive flash at the point of feed and this in turn will result in violent spouting.

**Short term solution**

It was now clear that the high pressure drop, flashing and spouting were the major causes of the very high undetermined loss through entrainment. The question of how the effect of the flashing could be minimised was then asked.

It was decided to redirect the feed from below the calandria to above the calandria. In this way the flash would not erupt through the syrup in the last effect vessel. The syrup would
boil normally and the flash would escape into the vapour space in the 4th effect body. The change was undertaken immediately. The syrup recirculation line for Brix control entered the 4th effect above the calandria. This pipe was modified and used to redirect all the feed from the 3rd effect to a position above the calandria in the 4th effect.

A splash plate was installed below the top hat in each last effect. The diameter was slightly larger than the cylindrical opening to the top hat. The intention of this installation was to reduce the amount of syrup getting into the top hat itself.

**Result of feed change**

When the modified evaporator was started, there was evidence of a small quantity of syrup trickling back into the vessel through the entrainment return system. The flash from the feed above the calandria could be seen through the sight glass. A small volume of syrup had entered the top hat in the vapour, but the volume was very small and the entrainment separator was able to handle this load and return all the syrup to the vessel.

Once the second evaporator line was modified and re-commissioned, sucrose levels in the cooling water started to drop slowly. Over a period of a few weeks the sucrose contamination reduced from >4500 ppm to <350 ppm sucrose. In the following weeks, the undetermined loss (UDL) reduced from around 6-7% on average to about 2% on average. After a number of weeks of optimisation, the undetermined loss reduced to values of 1-2% (Figure 15).

![Figure 15. 2012 weekly undetermined loss (UDL) showing a decline after the evaporator feed pipe changes were made.](image)

From Week 26, the UDL was consistently low, save for a high loss in the boil-off week at the end of the season.

HV had a low average Pol Factor of 95.7% for 2012. It could have been argued that the UDL decreased because of the low Pol Factor. Intensive investigations at HV suggest that the low Pol Factor is a function of an inadequate Direct Analysis of Cane (DAC) grab sampling system on the feeder table. A conventional DAC sampling system for both the A and B-lines will be installed during the 2012/2013 offcrop.
In the trend comparison between UDL and Pol Factor in Figure 16, it is important to note that the Pol Factor trend does not change significantly during the season, but the UDL does drop by a large margin after the changes to the evaporator feed were completed. This indicates that the UDL reduction is independent of the Pol Factor.

![UDL and Pol Factor graph](image)

**Figure 16. Weekly trend showing non-relationship between undetermined loss (UDL) and Pol Factor for 2012 season.**

*Strategy to resolve the syrup spouting in the last effect vessels*

The incidence of spouting in last effect vessels has received some attention in the Tongaat Hulett factories. It has been established that a high pressure drop between the second last and last effects of an evaporator system will lead to syrup spouting and potential syrup entrainment. At HV, the pressure drop between the last two effects is large under normal operating conditions.

Two spreadsheets were developed to calculate the volume of vapour per second that has to erupt through the body of liquid in the 1st, 2nd, 3rd and 4th effects. The calculations are tabled in Appendix 1 and Appendix 2.

The volume of flash in m$^3$/s and velocity of vapour in m/s for clean and fouled tube conditions are illustrated in Figure 17.

Since the feed system is located below the calandria, the flash must erupt through the tubes above the individual feed holes in the feed system. The flash will not spread across the entire area of the calandria and erupt equally through all the tubes. The flash probably covers an estimated maximum of 5% of the tube area located immediately above each feed hole. Based on this assumption, the vapour velocity of vapour flash in the tubes has been calculated for clean and fouled tubes by assuming that the vapour flows up these tubes only. The velocity of the vapour would be even greater if the presence of liquid was taken into account in the calculations.

The exceedingly high vapour velocities in the 4th effects will result in syrup spouting to the heights that were observed in these vessels.
Reduction of flash in the last effect
If the volume of flash in the last effect can be reduced, this will reduce the velocity of the flash up the calandria tubes. This can be achieved by partially flashing the syrup before it enters the feed system of the 4th effect. The partial flash is then directed into the 4th effect above the calandria. The balance of the flash will erupt from the feed when the syrup enters the last effect feed system and this will promote syrup circulation. Figure 18 illustrates the typical feed layout into the last effect where a partial flash tank has been incorporated.

Partial Flash of Feed to Last Effect

Figure 17. Vapour flow and vapour velocity for clean and fouled tubes.

Figure 18. Partial flash of feed into last evaporator vessel.
Conclusion

HV experienced a number of problems with the design and operation of the A and B-line evaporators from about 1995. It was established that low syrup Brix was due to uncontrolled flashing of evaporator condensates and poor extraction of heavy incondensable gas from the 2nd, 3rd and 4th effect calandrias. Sucrose contamination of V1 condensate and high undetermined loss was due to excessive spouting of juice in both kestner separators and both last effect vessels.

Reconfiguration of the condensate balance and flash lines effectively introduced steam traps for each effect, which re-established control of condensate flashing. An expedient addition of a heavy incondensable gas extraction pipe on the condensate outlet box solved the incondensable gas removal problem. After these changes, the syrup Brix increased to an acceptable average of >63% in the 2007 season.

The feed pipe in the Kestner separators was elevated to ensure that it was above the high juice level mark in the separators. Spouting and entrainment resulting from flash of the feed were minimised and sucrose levels in the V1 condensate dropped from 50 ppm to 5 ppm.

Excessive spouting in the last effect evaporator vessels was minimised by directing the feed above the calandria as a temporary measure. The sucrose entrainment into the cooling water system reduced significantly from >4500 ppm to <350 ppm and the UDL reduced from about 6-7% to about 1%. Plans are in place to minimise sucrose entrainment from the last effect vessels through the introduction of partial flash tanks on both A and B-line evaporators.

After the changes detailed in this paper had been made, more cane became available and HV has managed to comfortably handle the higher throughputs at higher imbibition rates.
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### Conditions Within the Vessel

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### Properties of Juice After Flashing

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<tr>
<td>Boiling point elevation [°C]</td>
<td>0.3</td>
<td>0.6</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Juice saturation temperature [°C]</td>
<td>109.4</td>
<td>102.9</td>
<td>77.7</td>
<td>56.4</td>
</tr>
<tr>
<td>Saturated juice enthalpy [kJ/kg]</td>
<td>425.5</td>
<td>372.6</td>
<td>266.7</td>
<td>182.3</td>
</tr>
</tbody>
</table>

### Thermodynamic Flash Calculation

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow of liquid stream after flash [t/h]</td>
<td>491.3</td>
<td>261.0</td>
<td>196.6</td>
<td>160.5</td>
</tr>
<tr>
<td>Flow of flash vapour stream [t/h]</td>
<td>7.5</td>
<td>3.1</td>
<td>8.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Flash vapour % liquid feed [%]</td>
<td>1.5%</td>
<td>1.2%</td>
<td>3.9%</td>
<td>3.1%</td>
</tr>
<tr>
<td>Volumetric flow of flash vapour [m³/s]</td>
<td>2.6</td>
<td>1.3</td>
<td>8.5</td>
<td>13.2</td>
</tr>
</tbody>
</table>

### Effect on Evaporator Boiling

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube diameter in effect [mm]</td>
<td>50</td>
<td>38</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Number of tubes in effect [-]</td>
<td>5,536</td>
<td>10,898</td>
<td>6,594</td>
<td>7,118</td>
</tr>
<tr>
<td>Open area for flow in tubes [m²]</td>
<td>10.9</td>
<td>12.4</td>
<td>12.9</td>
<td>14.0</td>
</tr>
<tr>
<td>Superficial vapour velocity [m/s]</td>
<td>0.2</td>
<td>0.1</td>
<td>0.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Velocity through 5% of tubes [m/s]</td>
<td>4.7</td>
<td>2.1</td>
<td>13.2</td>
<td>18.9</td>
</tr>
</tbody>
</table>
APPENDIX 2

JUICE FLASH CALCULATIONS
Hippo Valley Evaporator Station - Operation With a Fouled Final Effect

<table>
<thead>
<tr>
<th>JUICE INTO EFFECT NUMBER :</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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</thead>
<tbody>
<tr>
<td><strong>Properties of Incoming Juice</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juice flow rate [t/h]</td>
<td>498.8</td>
<td>261.2</td>
<td>199.5</td>
<td>163.6</td>
</tr>
<tr>
<td>Juice concentration (brix) [%]</td>
<td>14.4</td>
<td>27.5</td>
<td>36.0</td>
<td>43.9</td>
</tr>
<tr>
<td>Juice temperature [°C]</td>
<td>118.0</td>
<td>110.0</td>
<td>103.6</td>
<td>88.6</td>
</tr>
<tr>
<td>Juice enthalpy [kJ/kg]</td>
<td>459.4</td>
<td>398.3</td>
<td>356.5</td>
<td>288.9</td>
</tr>
<tr>
<td><strong>Conditions Within the Vessel</strong></td>
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<td></td>
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</tr>
<tr>
<td>Vessel vapour pressure [kPa(a)]</td>
<td>137.6</td>
<td>108.5</td>
<td>62.1</td>
<td>16.0</td>
</tr>
<tr>
<td>Vapour saturation temperature [°C]</td>
<td>108.8</td>
<td>101.9</td>
<td>86.8</td>
<td>55.3</td>
</tr>
<tr>
<td>Saturated vapour enthalpy [kJ/kg]</td>
<td>2,689.6</td>
<td>2,678.9</td>
<td>2,654.6</td>
<td>2,600.6</td>
</tr>
<tr>
<td><strong>Properties of Juice After Flashing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boiling point elevation [°C]</td>
<td>0.3</td>
<td>0.6</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Juice saturation temperature [°C]</td>
<td>109.1</td>
<td>102.5</td>
<td>87.7</td>
<td>56.4</td>
</tr>
<tr>
<td>Saturated juice enthalpy [kJ/kg]</td>
<td>424.2</td>
<td>370.6</td>
<td>300.2</td>
<td>181.8</td>
</tr>
<tr>
<td><strong>Thermodynamic Flash Calculation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow of liquid stream after flash [t/h]</td>
<td>491.0</td>
<td>258.1</td>
<td>194.8</td>
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<td>3.1</td>
<td>4.8</td>
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<tr>
<td>Flash vapour % liquid feed [%]</td>
<td>1.6%</td>
<td>1.2%</td>
<td>2.4%</td>
<td>4.4%</td>
</tr>
<tr>
<td>Volumetric flow of flash vapour [m³/s]</td>
<td>2.7</td>
<td>1.4</td>
<td>3.5</td>
<td><strong>19.0</strong></td>
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<td><strong>Effect on Evaporator Boiling</strong></td>
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<td>0.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Velocity through 5% of tubes [m/s]</td>
<td>5.0</td>
<td>2.2</td>
<td>5.4</td>
<td><strong>27.1</strong></td>
</tr>
</tbody>
</table>